A Discussion Paper On The Potential for Reducing CO_2 Emissions in Alberta

1988 - 2005

Executive Summary

Alberta
ENERGY

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Energy Efficiency Branch
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CHAPTER I.
INTRODUCTION

In March, 1990 the Alberta Ministers of Energy and Environment jointly announced the Clean Air Strategy for Alberta initiative. The initiative provides a consultative process through which the Alberta government can receive input from all stakeholders in the development of a comprehensive clean air strategy. This discussion paper has been developed as background material for and to encourage discussion on the carbon dioxide component of the strategy.

There is growing concern that the increasing atmospheric concentration of greenhouse gases may be leading to global warming. These gases — primarily carbon dioxide (CO_2), methane, oxides of nitrogen, and chlorofluorocarbons — are particularly effective in absorbing long-wave radiation from the earth's surface. This "greenhouse effect" is necessary to life on earth and its climate. The concern lies in the potentially negative effect on the global climate if the concentration of greenhouse gases continue to increase.

Carbon dioxide is estimated to contribute about 49 per cent of the greenhouse effect. Worldwide manmade non-biogenic emissions are in the order of 26,500 megatonnes (Mt) annually. The overwhelming majority of these is due to the combustion and use of hydrocarbon-based fuels.

Alberta produces approximately 22 per cent of the CO_2 emissions in Canada, the highest per capita emissions in the country. This is due largely to the presence of the energy production industry and because much of the province's electricity is produced from coal.

There is considerable debate about how manmade CO_2 emissions could be reduced. While there are numerous alternatives, this discussion paper concentrates on the reduction potential through energy efficiency and fuel substitution. Energy efficiency has a proven direct affect of reducing CO_2 emission by reducing the fuel consumed to do a particular task. In many cases the implementation of energy conservation measures result not only in reduction of CO_2 emissions but in economic benefit. In many respects improving the efficiency of energy use appears to have advantages for both the environment and the economy.

Where appropriate the paper also considers the CO_2 reduction effect of substituting less carbonaceous fuels, such as natural gas for oil or electricity (generated mainly from coal in Alberta). In these cases energy use is not necessarily reduced but since the carbon dioxide emission per unit of energy is lower for lower carbonaceous fuels, the net effect is a positive reduction.

1. OBJECTIVE

This discussion paper strives to identify a CO_2 reduction potential in Alberta through more efficient energy utilization and fuel substitution. It is important, throughout the discussion, to keep in mind that this potential for reduction is based on a particular set of theoretical economic and technical assumptions, and would therefore change if the assumptions change. Furthermore, the paper attempts to identify the maximum or ultimate reduction potential under the conditions assumed. It is recognized that in reality many factors could come into play which would tend to reduce the potential.

The paper is **not** intended to provide suggestions as to how to encourage or implement reductions. The reduction potential identified in this discussion could have significant economic implications (both positive and negative) if implemented. However these factors are not within the scope of the study and will not be discussed.

2. METHODOLOGY

The scope of the paper covers the period 1988 to 2005 for several reasons. The most current statistical data available on energy use is for 1988. It is also the base year for the most recent energy requirements forecast by Alberta's Energy Resources Conservation Board (ERCB). In its report 89-A - *Energy Requirements in Alberta, 1989 to 2003*, the ERCB supplies a forecast based on information supplied by a range of organizations in energy production, transportation, supply, and use.

The forecast period has been extended to 2005 because that year has been the focus of discussion, particularly as a target for reaching some reduced level of CO_2 emission. The Changing Atmosphere Conference in Toronto in 1988 called for a target of 20 per cent reduction of 1988 emission levels by the year 2005.

The research for this paper was carried out in the following manner:

a) In order to estimate reduction potential it is necessary to know current emissions. The first step was therefore to carry out an energy use and CO_2 emissions inventory for Alberta. Energy use data is often discussed in terms of fuel types. However the inventory segregates energy use and ultimately CO_2 emissions by end use sector. This has been done to assist in any future analysis of the potential for emissions reduction through a variety of demand-side initiatives such as energy efficiency and fuel switching.

b) Concurrently a list of energy conservation measures appropriate to Alberta was compiled. The list of some 300 measures was developed from a variety of sources, including energy audits conducted by the Alberta Department of Energy over the past 10 years. The list includes both technical measures (eg: upgraded insulation, ventilation control, heat reclamation), and operational measures (eg: temperature setback, good driving practice, maintenance practices).

c) To establish a reduction scenario for the years 1988 and 2005 it is necessary to apply the energy conservation measures to the energy inventory within the bounds of certain criteria. The criteria used are as follows:

i) **10-year simple payback** - In order to be included the energy reduction measure had to deliver a 10-year simple payback — the initial investment in technology or materials, plus any extra operating costs had to be offset by energy savings within 10 years, assuming constant dollars. This approach is similar to one used by the Federal/Provincial Task Force on Energy and the Environment in its 1989 report to the energy ministers, which identified "measures economically attractive to society". These are measures which may provide positive benefits to society on the basis of their energy savings but that may not be economically attractive from a private sector perspective.

ii) **Immediate implementation at 100 per cent penetration** - For the sake of simplicity it was assumed that most energy conservation measures applying to existing facilities were implemented in the first year (1988), and that the measures were adopted by 100 per cent of the population. Inherent is the assumption that a large opportunity for energy conservation exists, which is supported by energy audit experience. For some measures, such as vehicle and appliance replacement, a staged replacement over time rather than immediate implementation was assumed. The energy reduction potential from these measures is referred to here as the *retrofit potential.*

iii) **Diminishing returns** - The potential of conservation actions depends on what actions have been implemented beforehand. To estimate energy reduction potential in a particular sector, those measures meeting the 10-year payback criteria were applied on the basis of increasing capital cost. Savings calculated on a reducing balance.

iv) **Current technology for future facilities** - In forecasting the reduction potential in 2005, it was assumed that current, state-of-the-art technology would be used. No allowance for technological breakthroughs was made. In most cases this lead to an assumption that future facilities would be built at a level of energy performance 10 per cent better than that achievable after the implementation of all the retrofit measures meeting the payback criteria. The potential at the end of this period is referred to as the new technology or *future reduction potential.*

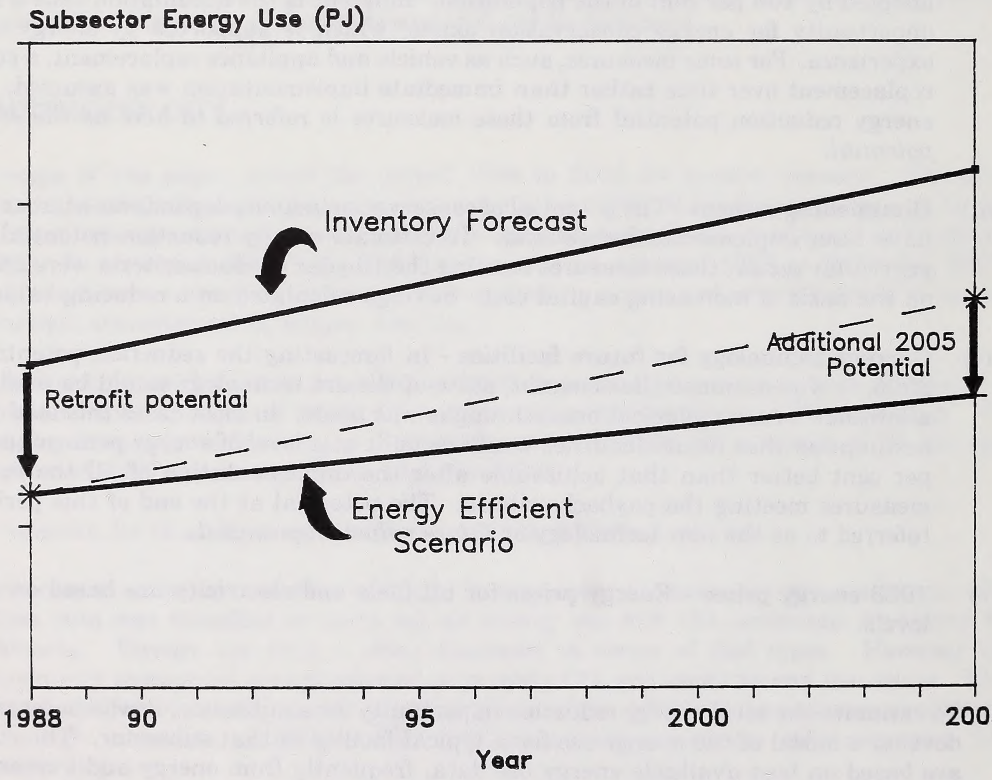
v) **1988 energy prices** - Energy prices for all fuels and electricity are based on 1988 levels.

d) To estimate the total energy reduction opportunity for a subsector, it was necessary to develop a model of the energy use for a typical facility in that subsector. The models are based on best available energy use data, frequently from energy audit records or engineering performance experience. Over 30 such models were developed.

Once the model for a subsector was developed, the full list of energy conservation measures and associated costs were applied as retrofits in order of increasing capital cost, and the payback calculated. With the application of each measure the energy use of the model facility was reduced before the next measures was applied. Ultimately, the 10-year payback criteria was exceeded and no further reductions were calculated. The net reduction in each type of fuel and in electricity demand was then computed.

Since the total provincial energy use in a subsector was known from the energy inventory, it was possible to extrapolate the model's energy use, and the estimated reduction potential, to the entire subsector. The result, expressed in petajoules (PJ) of energy saved, was considered the retrofit potential available in 1988.

The effect of the retrofit calculation carries through to the endpoint of the analysis — the year 2005. However, there is an additional reduction potential for new facilities being built in the future (1989 to 2005). To calculate this amount a reduction opportunity for new facilities (normally 10 per cent better performance than retrofit) was applied to the forecast 2005 inventory figure after it had been lowered because of retrofitting. Conceptually this method is perhaps best visualized via the figure below.



e) Having estimated the total energy reduction potential by fuel type for each subsector, it was then possible to calculate the resultant CO_2 reduction in megatonnes (Mt). An emission factor technique was used whereby each fuel savings is multiplied by a conversion factor in kilotonnes of carbon dioxide per petajoule. Since CO_2 generation from combustion is normally directly proportional to the amount of energy used, the calculation is essentially straightforward. Electricity-related CO_2 reductions are calculated through a different conversion factor (in kilotonnes per gigawatt-hour) which was developed based on the amount of CO_2 from coal and natural gas-fired generating plants divided by the total electric demand for the province.

CHAPTER II.
INVENTORY OF EMISSIONS

1. OVERVIEW

There is little historical data about Alberta's present carbon dioxide emissions or those predicted in the future. However, relatively good information on energy use in the province is available through Alberta's Energy Resources Conservation Board (ERCB). In most cases the conversion from energy use to CO_2 emissions is straightforward. The inventory therefore, focuses mainly on compiling energy production and utilization data.

a) Scope of the Inventory

The inventory includes CO_2 emissions generated mainly from energy-related fuel use and combustion in Alberta. It includes emissions from energy production activities, electric generation, energy transmission, and all energy end-use sectors.

Not all emissions are combustion-related. For example, sizeable volumes of raw CO_2 are released from underground formations in the production of oil and gas. Industrial operations also emit CO_2 from natural gas used as a feedstock, such as in the production of hydrogen through steam reformation. Some CO_2 is released from limestone and other materials in the processing of cement, lime and magnesium. All the above sources are considered in this inventory.

Not included are CO_2 emissions from wood. It is debatable whether or not emissions from wood, wood waste, and slash burning should be part of this inventory. Organic material eventually decomposes naturally and emits approximately the same volume of carbon dioxide as if it were burned. However, the rate of emission from wood is considerably speeded up when combusted. While this issue is beyond the scope of the present inventory, it may bear investigation in the future.

Emissions from municipal solid waste incineration are also not included, for similar reasons.

b) Methodology

Considerable effort was applied to allocating energy use data to end-use sectors. The ERCB's Integrated Model of Alberta, on which the energy requirements for the province are forecast, is an econometric model designed to look at aggregate energy use. It divides the analysis into broad categories such as the residential, commercial, industrial and transportation sectors.

This inventory attempts to distribute the data sectorially as much as possible to permit better analysis of the sources of CO_2 emissions. The distribution is difficult for several reasons. First, the ERCB model by its nature tends to disregard discrepancies in energy use data within sectoral boundaries as long as the aggregate total is reasonable. Secondly, detailed energy use statistics are frequently not available from Statistics Canada or other sources.

The energy use sectors are broken down into subsectors. For example, the commercial sector is divided into the subsectors of commercial buildings, education buildings, hospitals, other commercial, and street lighting. In most cases the subsectors represent groupings of facilities or industries with similar energy use profiles.

Once a distributed energy-use inventory by subsector is determined, the energy data is converted to CO_2 emissions by applying fuel-specific conversion factors. In most cases the factors, expressed in kilotonnes of CO_2 per petajoule of energy, are simply the higher heating value of the fuel, assuming 100 per cent combustion. Emission coefficients for process gas or feedstock gas are more difficult to determine. Process gas from oil sands, for example, is a mix of constituents, often varying with time. Carbon dioxide emissions from feedstock gas are process dependent.

Emissions from electricity generation are handled somewhat differently. In order to properly quantify the emissions from each subsector, it is necessary to allocate centrally-generated emissions based on sectoral electricity use. This is done by calculating an empirical CO_2 conversion factor for electricity consumption. The factor is calculated by dividing the total megatonnes of CO_2 emissions from coal and gas-fired generating facilities by the total secondary electric energy demand in gigawatt hours. Since Alberta exports little electric energy, this calculation is considered an appropriate way of allocating emissions to the various subsectors within the province.

Some electricity is produced through cogeneration in industrial operations such as oil sands and petrochemical plants. For the purposes of this inventory, such electricity use is given an emission factor of zero. The fuel used for cogeneration (normally gas) is attributed to fuel rather than electricity use and the appropriate CO_2 conversion factor applied.

c) Sources of Data

The majority of energy use data is taken directly from the ERCB 89-A Report *Energy Requirements for Alberta - 1989 to 2003*. In some areas where further breakdown was necessary Statistics Canada sources are used. Information on carbon dioxide generated from non-energy activities such as cement, lime and magnesium production was supplied by RTM Engineering Ltd. of Calgary.In some cases the ERCB data was redistributed within a specific sector to better reflect end use in the subsectoral areas.

2. ENERGY INVENTORY

The detailed energy inventory for Alberta is presented in **Table 1.** Total energy use in 1988 is estimated to be 2064 petajoules (PJ), increasing to 2918 PJ in the year 2005. Provincial energy demand increases relatively constantly until the turn of the century, at which point demand is forecast to largely level off. Carbon dioxide emissions growth essentially tracks energy growth.

The energy requirements forecast uses the ERCB's "high-case scenario" which makes the following assumptions:

- real GDP growth rate .... 3.2% per year
- energy demand growth rate .... 2.6% per year
- energy prices in 1988 .... $16.00/bbl of WTI crude
- energy prices in 2003 .... $29.46/bbl of WTI crude
- population growth .... 1.3% per year

Part (i) of Table 1 presents the data categorized by sector, with energy use for electricity generation identified as one of the sectors. Part (ii) is a similar analysis but here energy for electric generation has been distributed to each sector, proportional to the secondary electric energy demand for that area. Part (iii) of the table analyses the data by fuel type. **Figure 1** provides a graphical summary of the 1988 and 2005 sectoral energy use with electric generation shown separately.

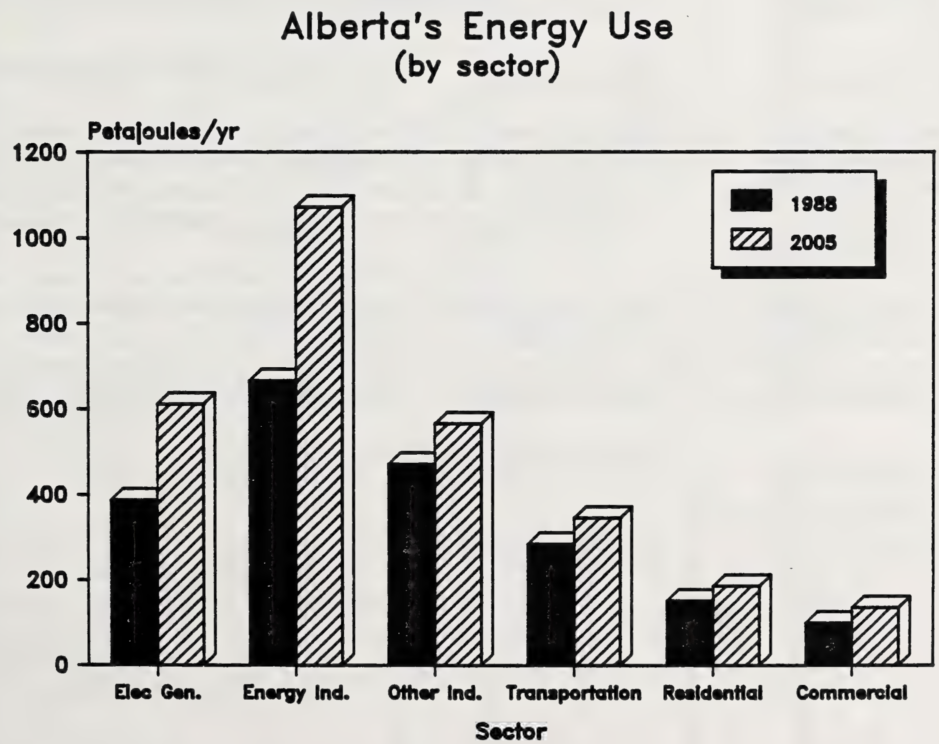


Figure 1

TABLE 1 - SUMMARY OF ENERGY USE BY SECTOR
(all numbers in PJs)

i) By Sector - electric generation separate

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	152	155	157	159	161	163	166	169	171	173	175	177	179	181	182	183	184	186
Commercial	100	103	105	108	110	113	115	118	120	123	125	126	128	130	131	132	134	136
Energy Industry	667	687	712	731	762	795	848	891	925	939	971	1031	1063	1084	1068	1068	1069	1072
Other Industry	472	483	486	487	491	496	497	497	512	513	561	562	591	595	595	585	575	566
Transportation	285	287	286	288	291	296	301	306	312	317	324	326	329	332	335	339	342	346
Electric Generation	388	395	411	426	442	460	474	494	517	527	547	561	571	583	589	596	604	612
Total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

ii) By Sector - electricity use allocated to sectors

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	228	232	236	240	244	249	253	257	263	268	273	278	281	285	287	291	294	297
Commercial	208	210	216	222	229	236	241	248	257	263	272	277	282	287	292	298	304	311
Energy Industry	778	805	836	858	895	933	992	1041	1080	1095	1132	1194	1227	1249	1231	1230	1231	1233
Other Industry	529	539	545	550	557	566	570	577	596	600	652	657	690	696	699	691	683	676
Transportation	285	287	287	289	292	297	301	307	313	318	325	327	329	333	336	340	343	347
Transmission Losses	36	37	38	40	41	43	43	45	47	48	50	51	52	53	53	54	54	54
Total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

iii) By fuel type

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
fuel gas	961	965	1000	1026	1064	1104	1163	1219	1238	1251	1267	1301	1325	1330	1321	1316	1312	1310
process gas	86	96	94	97	98	98	98	98	101	103	106	101	107	117	113	112	112	112
feedstock gas	258	287	287	288	288	288	289	283	305	310	368	397	426	431	431	429	427	426
propane	38	38	39	39	40	41	42	42	43	44	45	45	46	47	48	48	49	50
diesel	95	96	97	97	98	99	100	102	104	106	109	110	111	112	112	113	115	116
kerosene	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HFO	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
LFO	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2
coke	47	45	44	39	41	42	42	42	42	42	47	52	59	61	60	60	60	60
synthetic crude	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
gasoline	174	174	171	171	172	173	175	177	179	180	183	184	183	182	182	182	182	182
aviation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
turbo	25	26	28	29	31	33	34	35	37	38	40	40	41	42	44	45	46	48
NGV	0	0	0	1	1	1	2	2	2	2	3	3	4	5	7	8	8	9
coal	369	371	386	401	416	432	445	464	494	504	526	539	548	566	571	579	586	594
Total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

The energy industry category in Figure 1 consists of usage by the following sectors: oil fields, oil refineries, oil sands, gas processing and reprocessing, coal mines, pipelines, and gas flaring. The other industry category refers to energy use in the petrochemical, pulp and paper, cement plant, and other industrial subsectors. Electric generation includes both coal and natural gas energy used in generation plants as well as line losses in the transmission of electricity. It does not include additional fuel used in industrial cogeneration, which is attributed to sectoral fuel demand.

The total energy used in Alberta in 1988 is calculated to be 2064 PJ. This represents the energy used or burned in one form or another that contributed to CO_2 emissions. As such it is neither correct to refer to it as the province's secondary energy requirement (since it includes all fuel used for electricity generation), nor the primary energy requirement (since it does not include large volumes of uncombusted fuel exported or used in other forms).

By 2005 the total energy use is forecast to be 2918 PJ, a growth of 41 per cent. The largest growth is in the energy industry (primarily due to oil sands developments) and in electric generation because of rapidly growing electric demand.

In terms of fuel type, natural gas used as fuel in all its forms represents by far the largest energy source, at 961 PJ. Coal and feedstock gas are next at 369 PJ and 258 PJ respectively.

3. CARBON DIOXIDE INVENTORY

a) Emission Factors

To convert energy use to carbon dioxide emissions, the appropriate CO_2 emission factor for each fuel type is applied. The amount of carbon dioxide produced per unit of energy is a function of the type of fuel. In some cases, such as when fuel is used as feedstock, the amount of CO_2 produced is also dependent on the process.

The approach in constructing the CO_2 inventory was first to obtain a detailed energy-use inventory and then convert the energy quantities to carbon dioxide using an appropriate conversion factor. The conversion factors are normally the fuel's higher or gross heating value assuming 100 per cent combustion of hydrocarbons to carbon dioxide. The conversion factors used in the inventory are listed in the following table, in terms of kilotonnes of CO_2 per petajoule of energy.

CO_2 CONVERSION FACTORS

Fuel	Factor (kt CO_2/Petajoule)
Fuel Gas (assumes natural gas)	49.7
Propane (space heating and transportation)	59.8
Light Fuel Oil	73.1
Heavy Fuel Oil	74.0
Coal (sub-bituminous Alberta)	93.6
Kerosene	67.7
Diesel	70.7
Refinery Process Gas	51.0
Refinery Coke	86.0
Oil Sands Coke	89.4

Oil Sands Feedstock Gas	49.7
Oil Sands Process Gas	58.0
Petrochemical Feedstock	5.6
Flared Gas	49.7
Motor Gasoline	68.0
Synthetic Crude	70.0
Aviation Gasoline	69.4
Turbo Fuel	70.8

The factor used in converting electric demand to equivalent CO_2 emissions ranges from 0.983 in 1988 to 0.923 kilotonnes of CO_2 per gigawatt hour in 2005. It is calculated for 1988 as follows:

- 1988 coal used for electric generation . . . . 368.3 PJ
- 1988 natural gas used for electric generation . . . . 20.0 PJ
- total CO_2 emission from electric generation (including hydro with zero CO_2 emission) . . . . (368.3 x 93.6 kt/PJ) +(20.0 x 49.7 kt/PJ) = 35.5 Mt
- total electric demand in 1988 (including line losses) . . . . 36,084 GWh
- Therefore the equivalent electricity-to-CO_2 conversion is . . 0.983 kt/GWh

The factor changes slightly each year of the forecast as the coal-to-gas fuel ratio changes for electricity generation. Thus the appropriate factor was calculated for each year and multiplied by the electricity use in each sector in that year to properly attribute CO_2 emissions to the sectors.

The emission factor used for oil sands process gas is somewhat empirical as its composition varies widely with time and location. The value of 58.0 kt/PJ was derived from the ERCB using a weighted average of the design process gas streams of both Syncrude and Suncor. No allowance for future change has been assumed. A similar calculation was made to arrive at the value of 89.4 kt/PJ for oil sands coke.

Natural gas feedstocks can be converted to CO_2 via two processes in the petrochemical industry. The first is during steam reformation in the production of methanol and ammonia. The second occurs during the oxidation of residual carbon in the production of carbon black. Because large volumes of feedstock gas produce no carbon dioxide, it is necessary to first estimate the emissions of CO_2 from methanol, ammonia and carbon black operations, and then back-calculate an emission factor (5.6 kt/PJ) that could be applied to the total known petrochemical feedstock volume. This method is subject to considerable error as changes occur in the petrochemical industry. However, as only a global forecast for total feedstock is available it is necessary to use this technique.

While not requiring an emission factor, an estimate of the raw CO_2 released to the atmosphere is required. The ERCB made the estimate based on available information of CO_2 content in gas plant inlet volumes, CO_2 released from unprocessed gas used in field production, and CO_2 emitted from gas well testing, solution gas flaring and gas plant shut down flaring. The result was 5.8 Mt in 1988.

b) Inventory

The result is the CO_2 inventory presented in **Table 2**. In addition to the quantities of CO_2 related to fuel combustion from the energy inventory, the CO_2 inventory also includes raw CO_2 released in hydrocarbon production and from non-energy sources such as cement and lime manufacturing.

Total CO_2 emissions for 1988 are calculated to be 124.3 megatonnes By 2005 emissions are estimated to be 176.8 megatonnes, a growth of 42 per cent.

As in the energy inventory, electric generation and the energy industry are both the largest CO_2 contributors and exhibit the largest increase over the period. Fuel gas is the largest contributor by fuel type at 47.8 Mt. Coal is a close second at 34.6 Mt, reflecting the significantly higher emission factor per unit of coal energy combusted.

Figure 2 shows the sectoral data for both 1988 and 2005, with the CO_2 from electricity generation (35.5 Mt) allocated to the end use sectors. The result is a clearer view of the CO_2 contribution from the various sectors. Transmission losses are also shown as an "end-use" because of the difficulty in allocating transmission losses to a particular area. Note that the transportation, residential, commercial, and other industry sectors are all comparable in their CO_2 contribution when viewed in this manner.

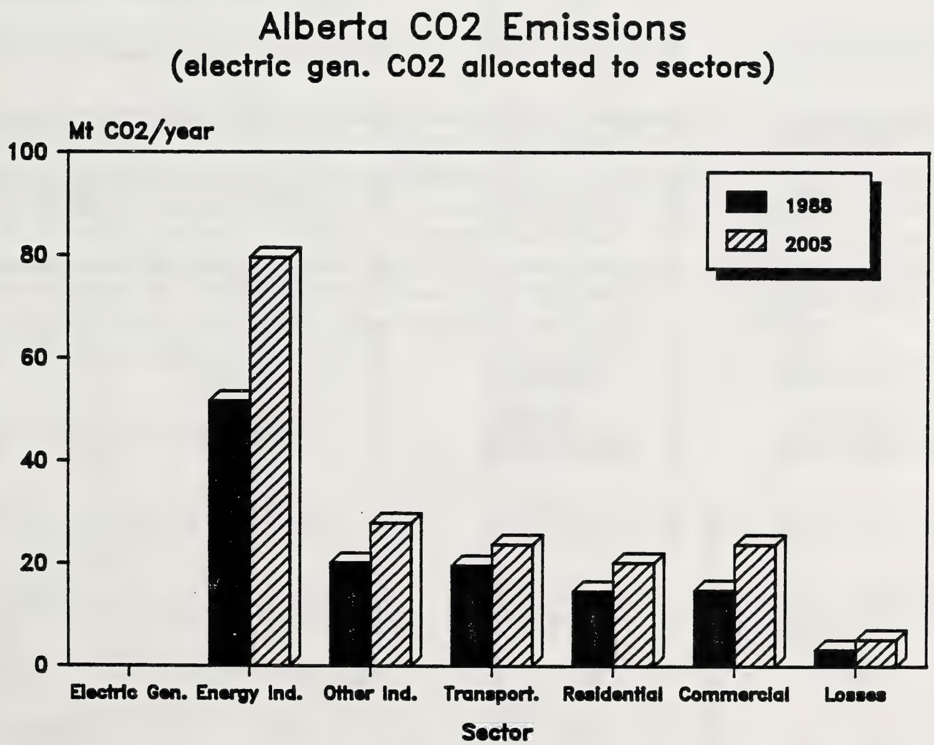


Figure 2

TABLE 2 - SUMMARY OF CO_2 EMISSIONS BY SECTOR
(all numbers in Megatonnes of CO_2)

i) By Sector - electric generation separate

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	7.7	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.8	8.9	9.0	9.1	9.1	9.2	9.3	9.3	9.4
Commercial	5.1	5.2	5.3	5.4	5.6	5.7	5.8	6.0	6.1	6.2	6.3	6.4	6.4	6.5	6.6	6.7	6.8	6.9
Energy Industry	41.6	42.5	44.0	45.0	47.0	48.9	52.1	54.5	56.6	57.4	59.5	62.7	64.6	65.7	64.6	64.3	64.1	64.0
Other Industry	15.0	14.7	14.8	14.9	15.1	15.4	15.5	15.8	16.0	16.1	16.5	16.5	17.2	17.7	17.8	17.6	17.4	17.3
Transportation	19.6	19.7	19.7	19.8	20.0	20.3	20.6	21.0	21.4	21.8	22.3	22.4	22.5	22.7	22.9	23.1	23.4	23.6
Elec Generation	35.5	35.9	37.3	38.7	40.2	41.8	43.0	44.8	47.0	47.9	49.7	50.9	51.8	52.9	53.5	54.2	54.9	55.6
Total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

ii) By Sector - electric generation allocated

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	14.7	14.8	15.1	15.4	15.7	16.0	16.3	16.6	17.0	17.4	17.8	18.1	18.3	18.6	18.8	19.0	19.3	19.5
Commercial	14.9	14.9	15.4	15.8	16.3	16.9	17.3	17.7	18.5	18.9	19.6	20.0	20.4	20.9	21.2	21.7	22.2	22.7
Energy Industry	51.7	53.2	55.2	56.5	59.1	61.4	65.1	68.1	70.7	71.6	74.1	77.5	79.5	80.7	79.4	79.1	78.8	78.6
Other Industry	20.2	19.8	20.2	20.6	21.1	21.8	22.1	23.0	23.7	24.0	24.8	25.1	26.2	26.9	27.2	27.2	27.2	27.3
Transportation	19.6	19.8	19.8	19.9	20.1	20.4	20.7	21.1	21.5	21.9	22.3	22.5	22.6	22.8	23.0	23.2	23.5	23.7
Transmission Losses	3.3	3.3	3.5	3.6	3.7	3.9	3.9	4.1	4.3	4.4	4.5	4.7	4.7	4.8	4.8	4.9	4.9	4.9
Total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

iii) By fuel type

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
fuel gas	47.8	48.0	49.7	51.0	52.9	54.9	57.8	60.6	61.5	62.2	63.0	64.7	65.8	66.1	65.7	65.4	65.2	65.1
process gas	4.8	5.3	5.2	5.4	5.4	5.5	5.5	5.5	5.7	5.7	5.9	5.7	6.0	6.6	6.3	6.3	6.3	6.3
feedstock gas	2.6	3.1	3.1	3.2	3.2	3.2	3.2	3.2	3.8	4.0	4.8	6.3	6.9	7.2	7.2	7.4	7.6	7.8
propane	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.8	2.9	2.9	3.0
diesel	6.7	6.8	6.9	6.9	6.9	7.0	7.1	7.2	7.4	7.5	7.7	7.8	7.8	7.9	7.9	8.0	8.1	8.2
kerosene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HFO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LFO	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
coke	4.2	4.0	3.9	3.5	3.6	3.7	3.7	3.7	3.7	3.7	4.2	4.6	5.3	5.4	5.4	5.4	5.3	5.3
synthetic crude	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
gasoline	11.8	11.8	11.6	11.7	11.7	11.8	11.9	12.0	12.2	12.3	12.5	12.5	12.4	12.4	12.4	12.4	12.4	12.4
aviation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
turbo	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4
NGV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5
coal	34.6	34.7	36.1	37.5	38.9	40.5	41.7	43.4	46.3	47.1	49.2	50.5	51.3	53.0	53.5	54.2	54.9	55.6
raw CO2	5.8	5.8	6.0	6.2	6.6	6.8	7.4	7.6	7.7	7.8	7.9	7.9	7.9	7.8	7.6	7.3	7.1	6.8
non-energy CO2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7
Total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

CHAPTER III.
ENERGY REDUCTION POTENTIAL

Energy reduction potential is determined separately for 1988 and 2005. The 1988 analysis involved the preparation of facility specifications and evaluation of energy conservation actions on a measure-by-measure basis. By comparison, the analysis for the remaining years is much more simplified in approach.

The main source of information used in the 1988 analysis is the data base of energy audit results that has developed through the operation of the Energy Bus energy audit service. Since 1980, over 2000 facilities throughout Alberta have been audited. This has established thorough energy use and potential savings data for many sectors. This data base, in conjunction with a number of other information sources, is used to develop sectoral energy prices, energy use profiles, sectoral population factors, energy conservation measure cost factors and potential energy and cost savings. A similar data base exists for the commercial transportation sector.

RTM Engineering Ltd., an Alberta consulting firm, developed similar energy use profiles, energy prices and cost factors for the primary industry sectors.

1. RETROFIT ANALYSIS

a) Energy Prices

Energy prices vary depending on size and class of utility customer groups. Each utility has its own unique rate structure that has been approved by the appropriate provincial or municipal regulatory agency. Utility rate structures for natural gas and electricity in 1988 were reviewed, including applicable discounts and taxes, and merged to yield average Alberta energy prices. One set was developed for houses, one set for commercial/institutional, a range of prices for primary industry, one set for other industry and by fuel type for transportation. Fuel prices for the primary industry sectors were determined by RTM Engineering. The resulting energy prices are as follows:

Sector	Natural Gas ($/GJ)	Electrical Energy (Cents/kW·h)	Electrical Demand ($/kV·A/Month)
Houses	2.24	5.0	--
Commercial and Institutional	2.17	3.013	7.06
Primary Industry	1.60-1.82	1.929	12.91
Other Industry	2.17	1.929	12.91

1988 prices were also determined for other fuels such as light fuel oil, coal, etc.

The price to be used for cogeneration electricity presented a difficulty for several reasons. Firstly, in any particular sector cogeneration can both displace electrical purchases from the grid and generate or add capacity to the grid. When it displaces purchases from the grid by reducing demand it has an energy value to the sector similar to the cost of purchased electricity. When it adds capacity to the grid it has a lower value to the sector since it represents the levelized avoided cost to the electric utilities.

Secondly, the appropriate prices for significant electrical cogeneration have not yet been tested through a rate hearing. The recent small power inquiry held by the ERCB established a cogeneration price of 4.5 cents per kilowatt hour, but for limited amounts of energy. It is recognized that if significant cogeneration capacity were brought on line at 4.5 cents per kilowatt-hour (1988 prices), it could have serious economic implications for the electric utilities and the net effect could be an increase in electricity rates.

For the purposes of this theoretical discussion it is assumed that cogeneration first displaces electrical purchases in each sector and that the value to the sector is equivalent to the average price of purchased electricity. If the cogeneration potential is great enough to reduce a sector's demand below zero, then it is assumed that the electricity is sold to the grid at a value of 4.5 cents a kilowatt-hour. While actual near-term levelized avoided costs may be somewhat less than this, it is consistent with the intent of the paper to look at a scenario which maximizes the potential for CO_2 reduction.

If the cogeneration or other energy conservation measures identified in this study were actually implemented to their full extent, there would be an impact on the prices of energy that were used in this discussion. This price sensitivity analysis is beyond the scope of the study. The study also does not attempt to assess any technical or regulatory barriers that limit the development of cogeneration capacity.

Transportation energy prices were established as follows:

Transportation Fuel Type	Price (Cents/Litre)
Gasoline	41.2
Diesel	38.7
Propane	20.0
NGV (Natural Gas)	24.6 equiv.
Aviation Fuel	77.8
Turbo Fuel	63.9
Syn Crude	38.7

b) Sector Models

The ERCB Report 89-A which forms the starting point for this paper refers to 28 energy-consuming sectors in six general groups. For the purpose of developing sector models for the evaluation of energy conservation measures, it was necessary to divide many of the sectors into subsectors. For instance, in eight of the 28 sectors, a total of 25 individual models were developed. The results of these models were merged into 16 subsectors, and savings measures evaluated for each. Those results were then recombined into results for the eight sectors. This sector division and recombination of results provides the best possible use of available data.

Subsector models were developed with two levels of detail. In the first, an energy use profile is established based on information from the energy audit data base. Average conditioned floor area, total fuel and electricity use and energy use breakdown into general areas are examples. In the second level of detail, facility specifications are developed consistent with typical facilities that have been audited. Examples of specifications include insulation levels, area of walls, windows and doors, heating plant efficiency, ventilation volume, motor horsepower, lighting and electrical power factor as well as building occupancy and temperature. Energy conservation measures are then applied to these more detailed models.

c) Energy Conservation Measures

A list of approximately 300 energy conservation measures was drawn up based on measures that are routinely suggested during energy audits, measures that are listed in various energy conservation reference materials and through discussion with suppliers and consultants. These measures generally fit into the following four categories:

Management:	Company policy, awareness, motivation, maintenance practices
New Construction:	Measures that are cost-effective when incorporated into the design of a facility.
Retrofit Measures:	Measures that can be implemented immediately or gradually into an existing facility in a cost-effective way.
Future Measures:	Measures that are not now cost-effective or require technical development.

Measures in the first and third category are considered in the analysis. For simplicity, groups of similar measures are consolidated into single measures.

d) Criteria

Energy conservation measures included in the analysis are measures that met certain criteria. Other criteria were established that affected how the measures were handled. These criteria are as follows:

Current energy efficiency:

Current energy utilization is based primarily on utilization factors from the energy audit data base. It is assumed that energy conservation measures had not yet been implemented in any sector.

Payback:

Only those measures that provide a 10-year simple payback are included in the analysis. Most measures offer relatively quick payback and many are of the low-cost, no-cost variety.
Penetration:

Measures that meet the payback criteria are assumed to be implemented by all energy consumers in the sector in 1988. Some measures are implemented on a more gradual basis throughout the 1989-2005 period.

Implementation Order:

Measures were implemented and savings calculated in the order of increasing cost to implement. The payback of each measure was not a factor in determining implementation order.

Diminishing Balance:

Savings calculations for each measure were done on the net energy utilization following the implementation of the previous measure. Therefore, the calculated energy saving for each measure is not as great as it might be for that measure alone.

e) Assumptions

A large number of specifications and factors were used throughout the analysis to maintain a uniform approach. Most of these were derived from energy audit data and some were straight assumptions. There were the following three types of such assumptions:

General

- All commercial facilities were assumed to be insulated to insulation levels of: Walls R10, Roof R8, Windows R1.53

- Heating plant combustion efficiency was assumed to be 75%

- Facility electric demand was determined by the following relationship:

$$\text{Demand (kV}\cdot\text{A)} = \frac{\text{Annual electric energy (kW}\cdot\text{h)}}{12 \text{ X } 300^{*} \text{ hours/month}}$$

* except 500 for health care facilities and 400 for pools.

- Heating degree days were assumed to be 10,458 (°F basis) and heating is required 365 days per year.

By Sector

Each of the energy conservation measures evaluated in the 1988 energy saving analysis was accompanied (in the main report) by relevant factors and specifications. For example, in the evaluation of heat recovery from the ventilation system of commercial buildings the following factors were shown:

heat recovery from 4388 CFM @ 72°F

50% heat recovery efficiency

capital cost of $2.00 per CFM

Additional

Other factors, mainly related to the cost of implementing energy conservation measures, are included in Appendix A within the list of measures.

f) Evaluation of Measures

Energy conservation measures were evaluated using the energy audit software of the Energy Bus program. The building heating and ventilation analysis uses the more simplified "degree-day" method rather than the "modified bin" method which is usually used for energy audits. Some of the longer payback measures need to be evaluated separately from the audit software because they are not normally included in energy audits. The measures that meet the 10-year payback criteria are placed in order of increasing cost of implementation and the savings calculated on the diminishing balance of energy utilization.

Energy substitution is accommodated by calculating the increase in energy use of one type of fuel to offset the reduction of another type. The efficiency of fuel utilization is taken into account.

The measures are listed in tables along with specific assumptions and the results of the calculations, by sector, in the main report. The overall results are as shown in **Table 3.**

The negative retrofit fuel savings in column one of Table 3 for the oil sands and gas processing sectors means that fuel use was increased to permit additional cogeneration to occur. The net effect reduces both energy consumption and carbon dioxide emissions. The negative electricity savings in column two of the table for general public vehicle indicates increased electrification of public transit such as LRT.

Of the total electricity reduction potential for 1988 of 21,639 Gwh, approximately 6200 GWh or 29 per cent is due to energy efficiency. The remainder is from cogeneration.

Note that the unit costs in column three of the table represent capital costs only. They do not take into account any upstream or downstream positive or negative effects on the economy.

Table 3

SUMMARY OF ANALYSIS of 1988 RETROFIT POTENTIAL	Fuel (PJ)	Electric Energy (GWh)	Unit Cost of Meas. $Million	Energy Savings $Million
1988 ERCB INVENTORY	**1675.6**	**36160.0**	**n/a**	**n/a**
1988 SUBSECTOR RETROFIT SAVINGS POTENTIAL				
HOUSES	38.7	1978.8	$823.1	$198.5
APARTMENTS	1.8	472.2	$38.2	$27.0
FARMS	5.1	195.9	$71.6	$21.1
COMMERCIAL BUILDINGS	17.6	1748.4	$465.6	$139.2
EDUCATIONAL BUILDINGS	4.1	269.1	$57.2	$23.6
HOSPITALS	2.2	245.0	$64.3	$16.3
OTHER COMMERCIAL	13.6	585.5	$156.9	$66.6
STREET LIGHTING	0.0	26.6	$9.1	$1.3
OIL FIELDS	10.9	133.0	$84.0	$23.5
OIL REFINERIES	4.1	21.7	$58.0	$8.4
OIL SANDS	-6.3	2210.3	$712.8	$118.5
PETROCHEMICAL	16.1	185.0	$237.5	$37.0
GAS PROCESSING	-8.2	6380.7	$1,347.5	$266.7
GAS RÈ-PROCESSING	1.3	198.0	$42.5	$10.4
COAL MINES	n/a	n/a	n/a	n/a
PULP & PAPER	0.4	365.6	$101.2	$17.0
CEMENT PLANTS	0.3	7.5	$3.5	$0.8
OTHER INDUSTRIES	61.6	3430.0	$1,655.9	$329.9
UTILITY PIPELINES	0.7	273.0	$66.8	$13.4
NOVA PIPELINES	0.6	0.0	$6.0	$0.9
GAS FLARING	27.7	2914.0	$365.7	$166.7
COMMERCIAL VEHICLES	35.4	0.0	$97.1	$388.7
GENERAL PUBLIC VEHICLES	22.1	-1.7	$134.7	$261.0
RAIL	0.1	0.0	$2.5	$1.2
AIR	0.3	0.0	$11.9	$7.4
FARM VEHICLES	0.2	0.0	$3.8	$1.9
Total	**250.4**	**21638.6**	**$6,617.3**	**$2,147.1**
1988 INVENTORY AFTER RETROFIT	**1425.2**	**14521.4**	**n/a**	**n/a**

2. FUTURE PERIOD ANALYSIS (1989 - 2005)

With the completion of the measure-by-measure analysis for 1988, a reduced energy requirement was determined for each sector, for each fuel type. The reduced energy requirement was further reduced by 10 per cent to account for energy efficiency measures that are only feasible in new construction. This revised energy requirement is divided by the actual 1988 energy requirement to give an energy intensity factor to be used in calculating future energy usage. The factor is multiplied by the energy growth predicted by the ERCB to yield a reduced energy requirement in 2005.

Expressed another way, energy efficiency measures that are feasible for facility retrofit in 1988 ought to be feasible for new construction plus a further 10 percent reduction. There is also new technology that is likely to become feasible prior to 2005 that will further reduce the energy requirement. Since the pace of technology development and commercialization is difficult to predict, the use of new technology is not factored into the analysis.

The primary industry sectors and transportation are handled differently. Energy growth in the primary industry sectors is determined based on estimates of required new plant capacity through new plants and expansions. This energy growth is reduced using the reduced energy intensity that was determined during the retrofit analysis. Energy use in the five transportation sectors is determined year-by-year and savings are incorporated on a more gradual basis through the period.

The overall results of the 2005 analysis are as shown in **Table 4.**

The negative values in the last column of the table indicate that those sectors have the potential to be net generators of electricity. That is through energy efficiency and cogeneration, they not only reduce their requirement for purchased electricity to zero, but also could produce excess electric energy for use elsewhere.

Table 4

SUMMARY OF ANALYSIS OF ENERGY EFFICIENCY POTENTIAL TO 2005				
SUBSECTOR	ALL FUELS (PJ)		ELECTRICITY (GWH)	
	1988 Inventory	2005 Potential	1988 Inventory	2005 Potential
HOUSES	108.7	91.5	5046	4908
APARTMENTS	15.8	17.8	1058	902
FARMS	27.3	19.3	972	954
COMMERCIAL BUILDINGS	48.7	41.4	6407	8277
EDUCATIONAL BUILDINGS	11.5	7.7	938	874
HOSPITALS	7.7	8.2	551	391
OTHER COMMERCIAL	32.2	25.6	1825	1895
STREET LIGHTING	0.0	0.0	266	359
OIL FIELDS	45.1	35.5	2505	2953
OIL REFINERIES	64.9	60.4	991	996
OIL SANDS	204.2	502.7	947	-1076
PETROCHEMICALS	339.0	371.1	2894	2779
GAS PROCESSING	221.8	278.5	1955	-7587
GAS REPROCESSING	10.4	13.5	2554	2889
COAL MINES	0.7	0.4	402	709
PULP AND PAPER	3.5	6.7	148	2304
CEMENT PLANTS	5.4	6.0	254	274
OTHER INDUSTRIAL	123.6	65.8	2035	-4566
UTILITY PIPELINES	6.5	9.8	941	803
NOVA PIPELINES	21.2	22.4	0	-235
GAS FLARING	92.7	71.7	0	-3216
COMMERCIAL VEHICLES	114.4	72.6	0	0
GENERAL PUBLIC VEHICLES	114.9	63.8	68	106
RAIL	12.3	17.1	0	0
AIR	26.0	33.7	0	0
FARM VEHICLES	17.1	13.3	0	0
TOTALS	**1675.6**	**1856.4**	**32757**	**15694**
		10.8% Increase		**52.1% Decrease**

The evaluation of energy conservation measures and calculation of reduced energy growth show that there is a large potential for energy savings in Alberta through energy conservation. In the 1988 retrofit analysis, 15 per cent of fossil fuel usage could be saved and 60 per cent of purchased electricity could be saved through energy conservation, including fuel substitution and cogeneration. Total energy cost savings among all energy consumers would be $2.2 billion per year in 1988 following the investment of $6.7 billion in energy conservation measures. Again, these dollar figures do not include any other economic or social costs or benefits which might occur if the measures were implemented.

By 2005 total fuel use is still expected to increase even after retrofit and energy efficient new construction. Fuel use in 2005 would be some 11 per cent greater than in 1988, down from the 38 per cent increase predicted by the ERCB. The requirement for purchased electricity would drop to 48 per cent of the 1988 level by 2005 instead of increasing by 69 per cent. Total electricity requirement is likely to increase even with improved energy efficiency but a major portion can be generated by cogeneration at points of end use.

CHAPTER IV
CO_2 REDUCTION POTENTIAL

The energy reduction potentials calculated in Chapter III are directly convertible to carbon dioxide reductions. Using the emission factor approach described in the inventory, the CO_2 reductions for the 1988 retrofit and the 2005 future periods for each fuel can be calculated. Since both fossil fuel and electricity use can be converted to a common equivalent in terms of megatonnes of CO_2, it is possible to add emission reductions from all energy types in all sectors to arrive at total CO_2 savings and reduced total emission levels in both 1988 and 2005. The results are presented in **Table 5.**

1. CUMULATIVE REDUCTION POTENTIAL

Table 5 indicates that under the conditions assumed for this paper, the total CO_2 emission level in 2005 could be reduced by 61.5 Mt by the year 2005. The emissions inventory, based on the ERCB energy forecast, predicted that CO_2 levels would increase by 52.5 Mt from 1988 to 2005. If all the energy conservation and fuel switching measures in the paper were implemented, a net reduction of 7.3 per cent in CO_2 emissions from the 1988 level by the year 2005 results.

The 1988 actual Alberta CO_2 emission level is 124.3 Mt per year. The potential exists by 2005 to reduce that level to 115.3 Mt per year.

2. RETROFIT AND FUTURE REDUCTION POTENTIAL

The retrofit CO_2 savings potential is estimated to be 34.3 Mt in 1988. This would reduce the 1988 emission level from 124.3 Mt per year to 90.1 Mt per year, or by approximately 28 per cent.

The future savings potential is slightly less than from retrofitting. In 2005, an additional reduction potential of 27.2 Mt exists due to future energy efficiency and fuel switching measures implemented between 1989 and 2005. The reduction is counterbalanced by energy and CO_2 emission growth over the period - the inventory predicts a growth of 52.5 Mt during the same time. It is therefore estimated that the retrofitted 1988 emission level of 90.1 Mt per year would increase to 115.3 Mt per year in 2005.

Table 5
Summary of CO2 Reduction Potential

	1988 Retrofit Reductn (Mt)	Future Reductn in 2005 (Mt)	Total Reductn in 2005 (Mt)	1988 Inventory Level (Mt/yr)	Reduced 1988 Level (Mt/yr)	2005 Inventory Level (Mt/yr)	Reduced 2005 Level (Mt/yr)	Percent Reductn from 1988 (%)
RESIDENTIAL SECTOR								
Houses (urban & farm)	3.90	1.69	5.58	10.42	6.52	14.50	8.91	14.5%
Apartments	0.55	0.34	0.89	1.83	1.27	2.58	1.69	7.5%
Farms/Rural	0.45	0.09	0.54	2.41	1.96	2.44	1.90	21.2%
Total residential sector =	4.90	2.11	7.02	14.7	9.75	19.5	12.50	14.7%
COMMERCIAL SECTOR								
Commercial Bldgs	2.60	2.14	4.74	8.72	6.12	14.32	9.58	-9.9%
Educational Bldgs	0.47	0.12	0.58	1.50	1.03	1.75	1.17	21.8%
Hospitals	0.35	0.15	0.50	0.93	0.57	1.24	0.74	19.6%
Other Commercial	1.29	0.72	2.01	3.47	2.19	5.04	3.04	12.6%
Street Lighting	0.03	0.00	0.03	0.26	0.23	0.36	0.33	-26.5%
Total commercial sector =	4.73	3.12	7.85	14.9	10.15	22.7	14.86	0.1%
INDUSTRIAL SECTOR								
Oil Fields	0.67	0.03	0.70	4.98	4.31	5.48	4.79	3.9%
Oil Refineries	0.23	0.06	0.28	4.45	4.23	4.44	4.15	6.7%
Oil Sands	1.12	4.36	5.49	13.14	12.02	33.18	27.70	-110.7%
Petrochemical	0.98	0.88	1.87	9.44	8.46	10.26	8.40	11.1%
Gas Processing	5.87	4.02	9.90	12.94	7.07	16.35	6.45	50.2%
Gas Re-Processing Plts	0.26	0.07	0.33	3.03	2.77	3.66	3.32	-9.9%
Coal Mines	0.00	0.00	0.00	0.43	0.43	0.68	0.68	-57.2%
Pulp and Paper	0.38	0.58	0.96	0.32	-0.06	4.00	3.04	-846.3%
Cement Plants	0.09	0.04	0.12	0.52	0.43	0.61	0.49	6.3%
Other Industries	6.65	4.92	11.57	8.59	1.93	10.72	-0.86	110.0%
Utility Pipelines	0.30	0.03	0.34	1.25	0.94	1.55	1.21	3.1%
NOVA Pipelines	0.03	0.49	0.51	1.05	1.02	1.41	0.90	15.0%
Gas Flaring	4.24	0.42	4.67	4.61	0.36	5.08	0.42	91.0%
Raw CO2 Release	0.00	0.00	0.00	5.80	5.80	6.81	6.81	-17.4%
Non-energy CO2	0.00	0.00	0.00	1.32	1.32	1.68	1.68	-27.3%
Total industrial sector =	20.83	15.90	36.74	71.9	51.04	105.9	69.16	3.8%

Table 5 (Cont'd)
Summary of CO2 Reduction Potential

	1988 Retrofit Reductn (Mt)	Future Reductn in 2005 (Mt)	Total Reductn in 2005 (Mt)	1988 Inventory Level (Mt/yr)	Reduced 1988 Level (Mt/yr)	2005 Inventory Level (Mt/yr)	Reduced 2005 Level (Mt/yr)	Percent Reductn from 1988 (%)
TRANSPORTATION SECTOR								
Commercial Vehicles	2.40	1.89	4.29	7.86	5.46	9.11	4.82	38.7%
General Public Vehicles	1.40	2.65	4.05	7.87	6.47	8.50	4.45	43.5%
Rail	0.00	0.23	0.23	0.86	0.86	1.45	1.21	-40.4%
Air	0.00	1.04	1.04	1.84	1.84	3.45	2.41	-30.9%
Farm Vehicles	0.00	0.28	0.28	1.20	1.20	1.22	0.94	21.7%
Total transportation sector =	3.80	6.09	9.89	19.6	15.83	23.7	13.83	29.6%
ELECTRIC TRANSMISSION LOSSES								
Total transmission losses sector =	0.00	0.00	0.00	3.27	3.27	4.92	4.92	-50.5%
TOTAL ALL SECTORS =	34.3	27.2	61.5	124.3	90.1	176.8	115.3	7.3%

3. SECTORIAL ANALYSIS

Figure 3 shows the potential 2005 CO_2 emission levels for each sector after energy conservation and fuel switching, compared to the 1988 and 2005 inventory levels. In every sector (except for electrical transmission losses where no reductions were calculated) the reduced 2005 emission level is less than the 1988 inventory level, although because of varying growth rates the percentage reduction differs considerably. Compared to 1988 levels, the percentage reductions by 2005 are:

- residential 14.7%
- commercial 0.1%
- industrial 3.8%
- transportation 29.6%

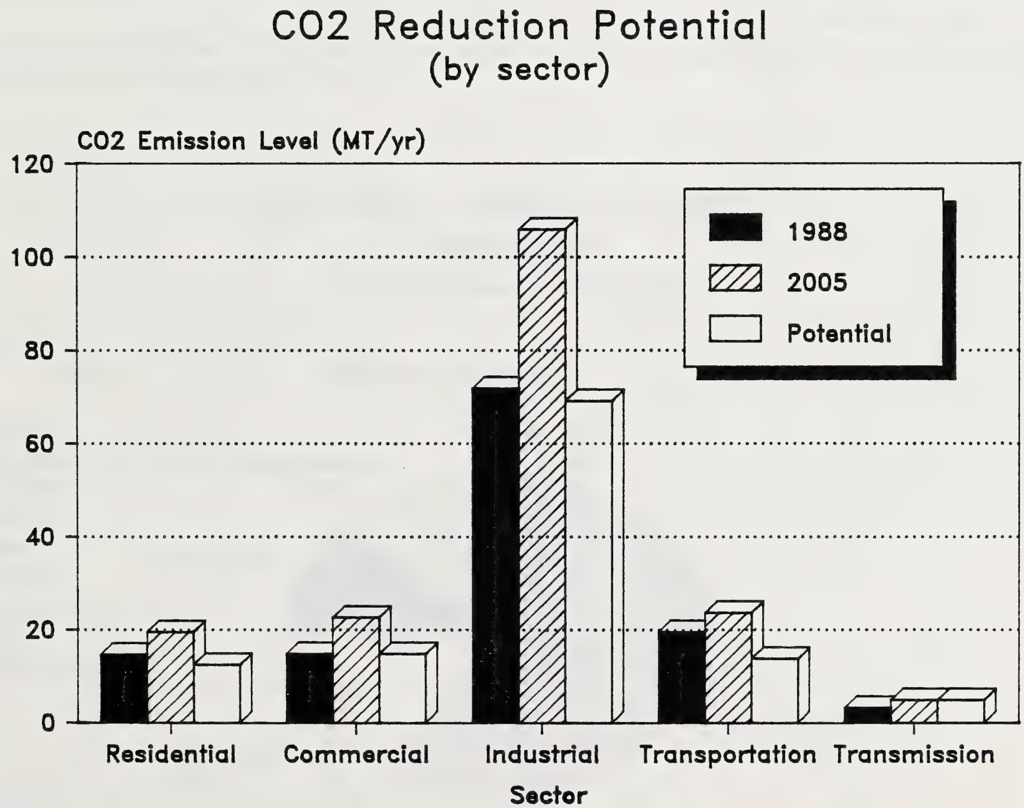


Figure 3

Figure 4 indicates the total amount of CO_2 reduction possible in the year 2005 for each sector. Out of a total reduction potential of 61.5 Mt, the industrial sector contributes 36.7 Mt or almost 60 per cent of the total reduction. The transportation sector is the next largest at 16 per cent, followed by the commercial (13 per cent) and the residential (11 per cent) sectors. Note that no reduction measures were considered for the CO_2 contribution from electrical transmission line losses.

Within the sectoral categories there were a number of subsectors with significant CO_2 savings potential. They are in order of decreasing size.

Other industries	11.6 Mt
Gas processing plants	9.9
Residential homes	5.6
Oil sands plants	5.5
Commercial buildings	4.7
Gas flaring	4.7
Commercial vehicles	4.3
Public vehicles	4.1

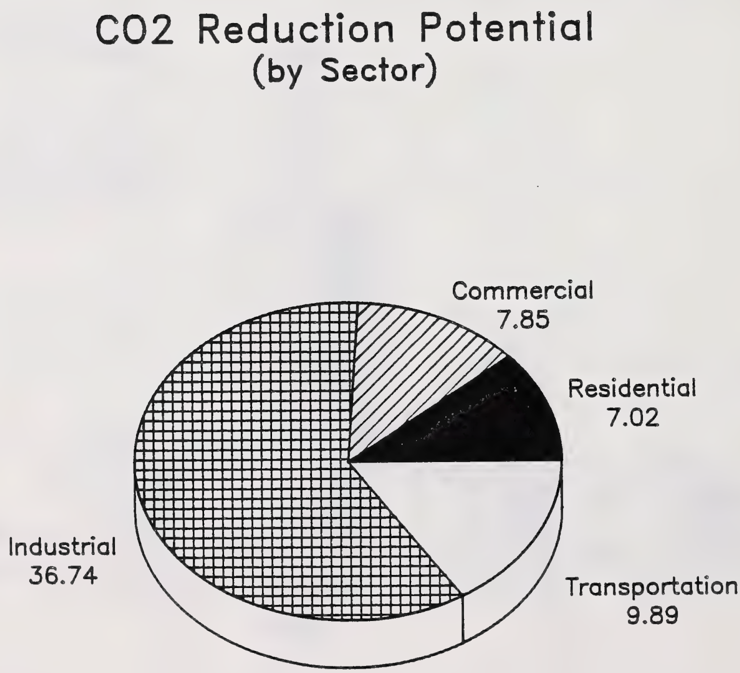


Figure 4

4. ANALYSIS BY FUEL TYPE

Table 6 below indicates the breakdown of carbon dioxide savings by fuel type. By far the largest reduction is due to reductions in electrical demand by energy conservation or by cogeneration of electricity with other fuels thereby reducing emissions from central generating plants. Electrical reductions account for 36.7 Mt or about 60 per cent of the total reduction potential in the paper.

Reductions in fuel gas use through energy efficiency is the second largest reduction category, providing 12.8 megatonnes or about 21 per cent of the total. The reduction potential is actually somewhat greater but to achieve some of the cogeneration electrical reductions additional natural gas was assumed to be used in several instances.

Reductions in transportation gasoline use contributes 7.0 Mt or 11 per cent of the total reduction potential. Note that CO2 reductions from NGV fuel use is negative, indicating a net increase in fuel as its assumed use is gradually increased as a substitute cleaner motor fuel.

Emission reductions from coke are also negative, since additional oil sands coke is assumed as an electrical generation fuel.

Table 6
CO_2 Reductions by Fuel Type

Fuel	Reduction Potential
fuel gas	12.77 Mt
process and feedstock gas	0.53
propane	1.02
diesel	2.78
coke	-1.05
gasoline	7.03
aviation fuel	1.04
NGV	-0.16
electricity	36.70

CHAPTER IV.
SUMMARY OF RESULTS

This discussion paper presents an analysis of energy and carbon dioxide reduction potential in Alberta **under one specific scenario**. A number of simplifying assumptions have been made in order to permit the analysis to be carried out. The most critical of these assumptions is of a 10-year payback criteria for investments in energy efficiency and the assumption that all measures meeting this criteria would be implemented at 100% penetration. Clearly these tend to result in savings estimates more toward the high end or the ultimate potential. This is the intent of the paper, recognizing that in reality many economic, political and lifestyle factors would come into play which might tend to diminish the savings potential.

In addition any forecast to 2005 can only be an estimate. Alberta is fortunate to have relatively good energy use data through the ERCB. However it must be remembered that the starting point for this discussion paper is the energy use and CO_2 inventories which in turn are dependent on the background assumptions made by the ERCB in their energy requirements estimates.

Under the conditions assumed for this paper the following results were developed:

a) Alberta's carbon dioxide inventory is estimated to be 124.3 Mt per year in 1988. This amount is forecast to increase to 176.8 Mt per year by the ERCB if no significant energy conservation measures are implemented.

b) Retrofit energy conservation measures in 1988 could achieve a savings of 250 PJ of fossil fuels and 21,639 GWh of electrical energy. The capital cost of doing so would be $6.7 billion and would result in a first year savings of $2.2 billion per year. The average payback of the investment would be 3.1 years.

   Adding future energy savings potential, the province's 2005 total fossil fuel use would grow by 11 per cent of the 1988 level, down from an estimated growth of 38 per cent with no energy conservation measures. Electrical use would decrease by 48 per cent of 1988 levels by 2005. The overall result would be a net decrease in Alberta's energy use.

c) The annual carbon dioxide reduction resulting from the conservation measures envisioned in this paper would be 61.5 Mt per year in the year 2005. This would reduce the 1988 emission level of 124.3 Mt by about 7.3 per cent. Retrofitting accounts for approximately 56 per cent of the savings, improvements to future facilities contributes the remainder in 2005.

   All energy end use sectors show a reduction from 1988 emission levels. The largest savings potential is in the industrial sector (36.7 Mt) with almost 60 per cent of the total. The commercial, residential and transportation sectors provide CO_2 savings opportunities of 11 to 16 percent.

   By fuel type, the electricity reduction potential contributes 60 per cent of the total carbon dioxide savings, or 36.7 Mt. Fuel gas is the next largest providing 12.8 Mt savings potential.

This paper shows that the potential for carbon dioxide emission reductions is significant. To what degree this potential can or should be achieved remains to be seen. It is evident however that numerous opportunities exist for energy efficiency and fuel substitution to play a role in any reduction scenario. Some of the measures discussed in this paper are already economic in their own right but face certain barriers to their implementation. Other measures are not currently attractive under conventional business conditions. For those measures to be undertaken would require significant shifts in the priorities of the Alberta industry and public. The Clean Air Strategy for Alberta process now underway is intended to generate discussion in that regard. This paper provides some input to that discussion.

Appendix A

List of Energy Conservation and Fuel Substitution Measures

Energy Conservation Measures	Payback (years)
SINGLE RESIDENTIAL	
1. Manual Temperature Setback	0.0
2. Water Tank Temperature Setback	0.0
3. Manual Lighting Control	0.0
4. Retrofit Insulate Water Tank	2.6
5. Restrict Hot Water Use	3.2
6. Use of Timers	2.7
7. Improve Airtightness	4.9
8. Improved new appliances	4.4
9. Conversion of Elec to Gas (ranges & dryers)	4.5
10. Install Mid-eff Furnace	8.5
APARTMENTS	
1.House Keeping/Maint.(2%Eff.Improvement).	0.0
2.Parkade - reduce operating temp.	0.0
3.Blg.Heat Loss - set back temp.	2.1
4.Heating Pump - reduce hours on.	1.2
5.Pool Cover - fan savings.	0.4
6.Ventilation - reduced hours.	1.6
7.Power Factor Improvement	1.0
8.Fluorscent lights - use low wattage tubes.	1.7
9.Exit Signs - 40,000 hour multi-bulbs.	1.6
10.CO control - Parkade Exh.	2.1
11.Vehicle Block Heaters - use power saver cords	1.2
12.Weatherstrip windows & doors.	1.3
13.Fluor.Lights - use E.E.ballasts.	3.6
14.Heat Recovery	5.2
15.Showers - use low flow heads.	3.0
16.Incandescent bulbs - convert to fluor.	1.0
17.Laundry Dryers - convert to nat.gas type	1.2
18.Electric Motors - use energy efficient.	5.2
FARMS/RURAL	
1.House Keeping/Maint.(2%Eff.Imp.)	0.0
2.Shop - reduce temperature.	0.0
3.Veh.Block Htrs.-use P.S.cords.	1.5
4.Fluor.Lights-use l.w.tubes.	2.5
5.Weatherstrip doors.	0.9
6.Fluor.Lights-use E.E.ballasts.	9.2
7.Loading Doors - insulate.	5.0
8.Inc.Lights-use compact fluor.	4.1
9.HID Yard Light-use energy efficient.	6.9

Energy Conservation Measures	Payback (years)
COMMERCIAL BUILDINGS	
1.House Keeping/Maint. (2%Eff.Imp.)	0.0
2.Kitchen Vent. - reduce hours.	0.0
3.Parkade - set back temperature.	0.0
4.Pool-cover at night.	1.0
5.Heating Pumps - shut off.	1.0
6.Showers-use low flow heads.	1.8
7.Ventilation - shut off.	0.1
8.Exit Signs - use multi type bulbs.	1.2
9.Heat recovery - cooler compressors.	9.0
10.Inc. Lights-use compact halogen.	6.2
11.Vehicle Block Heaters-cycle.	2.7
12.Misc. Lights - shut off.	4.0
13.Heat Recovery - ventilation.	7.7
14.Weatherstrip doors & windows.	6.3
15.Fluor.Lights-use l.w.tubes.	1.8
16.Parkade HVAC - CO control.	1.4
17.Dishwasher- use low temp. type.	5.4
18.Power Factor Correction.	1.4
19.Blg.Heat Loss-set back temp.	2.2
20.Inc. Lights-use compact fluor.	1.9
21.Elect.Motors-use energy efficient.	5.6
22.Cogeneration	6.6
23.HID Lights-use energy efficient.	7.0
24.Fluor.Lights-use E.E.ballasts.	6.1
25.Misc.Lights - delamp.	6.2
26.Laundry Dryer-use energy eff.	1.8
EDUCATIONAL BLGS.	
1.House Keeping/Maint. (2%Eff.Imp.).	0.0
2.Shut off furnaces in summer.	0.0
3.Ventilation - reduce air volume.	0.0
4.Weatherstrip doors & windows.	0.9
5.Exit Signs - use multi-type bulbs.	3.1
6.Shut off heating pumps above 55'F.	2.4
7.Vehicle Block Htrs-use P.S. cords.	3.7
8.Power Factor Correction.	1.5
9.Ventilation - reduce hours.	0.3
10.Fluor.Lights-use low wattage tubes.	2.4
11.Building Heat Loss - set back temp.	2.7
12.Lighting - delamp.	3.6
13.Fluor. lights - use E.E. ballasts.	8.4
14.Elect. Motors-use energy efficient.	2.2
HOSPITALS	
1.House Keeping/Maint. (2%Eff.Imp.)	0.0
2.Lights - switch off.	0.8
3.Weatherstrip doors & windows.	3.1
4.Heating Pumps - reduce hours.	0.2
5.Ventilation - reduce hours.	0.1
6.Exit Signs - use energy efficient.	0.8
7.Blg.Heat Loss - set back temp.	1.3
8.Vehicle Block Htrs-use P.S. cords.	1.6
9.Power Factor Correction.	1.4
10.Fluor.Lights-use l.w.tubes.	2.1
11.Inc.Lights-use compact fluor.	2.3
12.Misc. Lights - delamp.	7.2
13.HID Lights-use energy efficient.	5.2
14.Electric Motors-use energy eff.	4.8
15.Heat Recovery-boiler stack.	7.9
16.Vent.Motors-use VFD's.	2.5

Energy Conservation Measures	Payback (years)
17.Sterilizer-convert to nat.gas	3.7
18.Fluor.Lights-use E.E. ballasts.	9.6
19.Heat Recovery - ventilation.	7.1
20.Cogeneration	7.2
21.Dishwasher-use low temp.	4.1
22.Laundry Dryers-use energy eff.	2.4
OTHER COMMERICIAL	
1.House Keeping/Maint.(2%Eff.Imp.).	0.0
2.Lights - adjust ice lights.	0.0
3.Ice shaving melt - dump outside.	0.0
4.Sauna - reduce hours on.	0.3
5.Insulate Zamboni roll-up doors.	2.4
6.Showers - use low flow.	1.1
7.Insulate hot water tanks.	1.0
8.Pool - cover when not in use.	0.3
9.Power Factor Correction	1.4
10.Weatherstrip doors & windows.	0.4
11.Destratification.	8.6
12.Exit signs - use multi type bulbs.	2.6
13.Ice Plant Mtrs.-use energy eff.	5.4
14.Heat Recovery-compr.hotgas.	7.5
15.Lights - delamp.	4.5
16.Heat Recovery - pool exhaust.	6.3
17.Fluor.Lights-use l.w.tubes.	2.4
18.Bldg.Heat Loss-set back temp.	0.7
19.Elect.Motors-use energy eff.	6.1
20.HID Lights-use energy efficient.	8.6
21.Ventilation-shut off exhaust.	0.9
22.Cogeneration	7.3
23.Fluor.Lights-use E.E.ballasts.	7.2
24.Inc.Lights-use compact fluor.	2.8
25.Furnaces-use energy efficient.	0.6
STREET LIGHTING	
1.HID Lights - use energy efficient.	6.9
OIL FIELDS	
1.Energy efficient motors., draft control etc.	0.0
2.Load level production., static treaters.	0.0
3.Engine efficiency improvements	6.1
4.New heaters/treaters incremental costs for improved design	6.1
5.Lighting improvement.	2.4
6.Better additives incremental	6.1
7.New burners incremental cost for improved design	6.1
8.Insulation repairs and improvements	4.9
9.New reconditioned electrostatic treaters	6.1
10.Resize jets, adjust burners, draft control	4.7
OIL REFINING	
1.High efficiency small motors.	0.0
2.Operations and maintenaince upgrades.	0.0
3.Operations and maintenaince.	0.0
4.High efficiency lighting	1.1
5.Auto lighting controls.	1.0
6.Air cooler revisions.	4.1
7.Oversize motor replacement.	4.0
8.Building heating upgrade.	9.5
9.Expanders-liquid.	4.5
10.Pump system revisions.	3.9
11.Insulation upgrade.	9.9
12.Fired heaters controls.	9.1
13.Upgrade distillation.	9.2
14.Added furnace preheat.	9.6

Energy Conservation Measures	Payback (years)
OILSANDS	
INSITU OIL SANDS & OIL SAND MINING	
1.Energy Efficient Small Motors	0.0
2.Oper. and maint. improv.	0.0
3.Oper. and maint. improv.	0.0
4.High efficiency small motors.	4.6
5.Lighting improvements.	1.2
6.Auto Lighting & Misc. Controls	2.8
7.Cooling System Revision	4.4
8.Blg.Heat Loss - upgrade.	8.5
9.Improved Hydrogen Plant Operation	8.7
10.Pump system revisions.	4.4
11.Expanders on Liquids.	4.5
12.Extraction Changes.	3.2
13.Heat exchanger improvements.	5.8
14.Fixed Heater Controls	8.1
15.Enhanced Heat Recovery	7.5
16.Insulation improvements.	8.9
17.Upgrade Distallation.	9.3
18.Heater improvements.	7.7
19.Added Furnace Preheat	10.1
20.Process improvements.	8.1
21.Coke Gasification	9.9
PETROCHEMICALS	
1.High efficiency small motors.	0.0
2.Operations and maintenaince upgrades.	0.0
3.Operations and maintenaince.	0.0
4.High efficiency lighting	1.2
5.Auto lighting controls.	1.2
6.Air cooler revisions.	4.5
7.Oversize motor replacement.	4.6
8.Pump system revisions.	4.8
9.Building heating upgrade.	8.6
10.Added furnace preheat.	9.9
11.Expanders-gas & liquid.	4.5
12.Insulation upgrade.	9.4
13.General controls improvements and catalyst changes.	8.5
14.Fired heaters controls.	6.9
15.Process changes.	6.9
16.Upgrade distillation.	9.2
GAS PROCESSING PLANTS	
1.Higher efficiency motors	0.0
2.Cogeneration to be added over life.	0.0
3.Load level production. (field use)	0.0
4.New burners incremental cost for improved design. (gathering)	0.0
5.Improved burner maintenance. (plant)	0.0
6.Shutting off lights manually or automatically.	1.2
7.Compressor exhaust heat for glycol regenerators. (field use)	3.6
8.Compressor exhaust gas for dhey units. (gathering)	3.3
9.Combustion air economics. (gathering)	3.6
10.Lighting improvements	1.8
11.Resize jets, adjust burners, draft control etc. (gathering)	2.1
12.Convert from heaters to dehydrators (attrition of heaters). (field use)	0.4
13.Insulation repairs and improvements. (field use)	4.2
14.Compressor efficiency improvement. (field use)	4.3
15.Combustion air economics. (field use)	3.3
16.Resize jets, adjust burners, draft control etc. (field use)	1.5
17.New burners incremental cost for improved design. (field use)	3.8

Energy Conservation Measures	Payback (years)
18.Improved insulation and fire-brick maintenance. (plant)	3.0
19.Compressor efficiency improvement. (gathering)	4.4
20.Improved instrumentation draft control etc. (plant)	3.1
21.Engine exhaust heat exchangers. (plant)	4.5
22.Engine/compressor efficiency improvements. (plant)	3.3
23.Flue gas economizers and improved exchangers. (plant)	4.2
24.Power factor improvement.	2.1
25.Cogeneration	7.2
GAS RE-PROCESSING PLANTS	
1.Higher efficiency motors	0.0
2.Better heat exchangers.	3.0
3.Compression improvements.	4.7
4.Lighting improvements	4.4
5.Process improvements.	4.2
6.New turbines.	3.3
7.Cogeneration	10.1
PULP AND PAPER	
1.High efficiency small motors.	0.0
2.Thermal systems operations and maintenaince.	0.0
3.Improved operations and maintenaince.	0.0
4.Lighting improvements.	1.3
5.Insulation improvements.	8.3
6.Building heating efficiency.	7.5
7.Pump circuit improvements.	4.3
8.Upgraded controls and process changes.	9.1
9.Waste wood generation.	8.8
CEMENT PLANTS	
1.Energy efficient motors.	0.0
2.Thermal operation and maintenaince.	0.0
3.Electrical operations and maintenance.	0.0
4.Improved lighting.	2.3
5.Added variable speed drivers.	3.4
6.Control and under loaded motor replacement.	3.8
7.Building heating improvements.	7.1
8.Misc. control and process changes.	8.1
OTHER INDUSTRIAL	
1.House Keeping/Maint. (2%Eff.Improvement).	0.0
2.Electrical Billing - load schedule.	0.0
3.Showers - low flow heads.	0.6
4.Cleaning tank - cover.	0.8
5.Weatherstrip doors.	0.3
6.Ventilation - reduce hours.	0.1
7.Air Compressor - repair leaks.	1.1
8.Boiler maintenance.	0.1
9.Insulate tanks, heat exchangers.	0.5
10.Electric motors - convert to variable frequency drive.	1.6
11.Insulate pipes.	2.9
12.Heat Recovery - air compressor (screw type).	5.4
13.Vehicle Block Heaters - cycle.	1.9
14.Building heat loss - set back temperature.	1.2
15.Fluorescent lights - use low wattage tubes.	1.6
16.Overhead Doors - insulate.	4.3
17.Inc. lights - convert to equivalent compact fluorescent.	1.6
18.Power Factor Correction.	0.7
19.Heat Recovery - boiler stack.	2.1
20.Fluorescent lights - use energy saving ballasts.	5.3
21.Destratification.	5.0

Energy Conservation Measures	Payback (years)
22.Heat Recovery - process exhaust.	0.9
23.HID lights - convert to energy efficient.	6.0
24.Electric motors - use energy efficient.	5.6
25.Heat Recover - process hot water.	1.8
26.Cogeneration	9.8
UTILITY PIPELINES	
1.Improved power factor. (gas p/l)	2.3
2.Manual and automatic lighting shut-off.(gas p/l)	1.3
3.Lighting improvements. (gas p/l)	0.4
4.Manual & auto. lighting shut-off (oil p/l)	1.7
5.Improved power factor. (oil p/l)	6.0
6.Control changes to permit floating.	3.1
7.Lighting improvements (oil p/l)	3.2
8.Improved engine efficiency	2.8
9.Expanders	7.8
NOVA PIPELINES	
1.Improved operations planning.	0.0
2.Compressor inlet Conversion.	9.8
3.Misc. system changes.	9.8
FLARED GAS	
1.More dependable electricity supply (gas plant)	0.0
2.Better crude stabilization and treating (oil fields)	0.4
3.Portable eletricity generation for well tests	0.2
4.More efficient and less gas turbine	9.4
5.Instrumentation to use line pack and	4.9
6.Instrumentation to reduce venting in psuedo emergencies (gas plant)	5.7
7.Better acid gas solvents. (gas plant)	6.8
8.Better crude stabilization and treating. (oilfields w/o GC orders)	3.2
9.Electricity generation. (oilfields with orders)	2.4
10.Tie-in marginal batteries (oilfields with orders) for extended well tests. (gas fields)	5.7
11.Instrumentation to use line pack and shut in wells.(gas fields)	9.4
12.Additional gas conservation. (oilfields w/o orders) starts (re-processing plants)	5.6
13.Electrical generation. (oilfields w/o GC orders)	1.6

Energy Conservation Measures	Payback (years)
COMMERCIAL VEHICLES	
1. Route Planning	0.1
2. Driver Training	0.2
3. Vehicle Maintenance	0.5
4. Vehicle Retrofits	0.3
5. Fuel Conversion	3.0
6. Vehicle Selection	2.0
7. Intermodal Shift	6.4
GENERAL PUBLIC VEHICLES	
1. Route Planning	0.0
2. Driver Training	0.2
3. Vehicle Maintenance	0.5
4. Vehicle Retrofits	0.7
5. Fuel Conversion	4.0
6. Vehicle Selection	2.0
7. Urban Traffic Management	9.7
RAIL TRANSPORT	
1. Railway Fuel Economy Improvements	2.1
AIR TRANSPORT	
1. Operations Planning	2.0
2. New Aircraft Fuel Economy	2.0
FARM TRANSPORT	
1. Agricultural Advances	2.0
2. Equipment Replacement	2.0